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Some features of high energy hadron-hadron collisions

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High energy charged particle multiplicity data in pp, $\bar{p}p$, $\pi\pm p$ and $K\pm p$ collision obtained in recent years (compilation by Ammosov *et al* 1973, Czyzewski & Rybicki 1972) show some regularities as pointed out by various workers. Malhotra (1963) and also Wroblewski (1972) and Czyzewski & Rybicki (1972) have shown that the ratio $< n_c > /D$ tends to a constant at high energies when $< n_c >$ is the average charge particle multiplicity and $D = (< n_c^2 > - < n_c >^2)^{\frac{1}{2}}$ is the dispersion. The limiting value is fairly close to 2 for all reactions. Ammosov *et al* (1973) and Wroblewski (1972) have shown that if we plot $< n_c >$ and Mueller correlation parameter f_2 against the total available energy Q then there is a tendency for the experimental points to lie on single universal curve. In this note we have shown that if we plot $< n_c\,(n_c-1) > / < n_c >$ against Q there is a equally good tendency for the data to lie on a universal curve which is shown in figure 1. It is also shown that the following three functions

$$R_1 = \frac{1}{< n_c >}\left\{\frac{< n_c(n_c-1)>}{D}+1\right\} \quad \ldots \quad (1)$$

$$R_2 = \frac{1}{< n_c >}\left\{\frac{< n_c(n_c-1)>}{< n_c >}+\frac{1}{D}\right\} \quad \ldots \quad (2)$$

$$R_3 = \frac{1}{< n_c >}\left\{\frac{< n_c(n_c-1) >}{< n_c >}+\frac{< n_c >^2}{D}\right\} \quad \ldots \quad (3)$$

are almost independent of energy and have nearly the same value for the above six reactions. Eqs. (2) and (3) give a relation between $< n_c >$ and D namely,

$$D = \frac{1}{R_3 - R_2}\left(< n_c > - \frac{1}{< n_c >}\right). \quad \ldots \quad (4)$$

For pp and $\pi^- p$ reactions using the average values of R_2 and R_3 one can get

$$D = \tfrac{1}{2}\left(< n_c > - \frac{1}{< n_c >}\right). \quad \ldots \quad (5)$$

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This is similar to Wroblewski relation

$$D = A(<n_c> - B), \qquad \ldots (6)$$

where A and B are constants (Wroblewski 1973). For pp collision

$$B = A = 0.576 \pm 0.008.$$

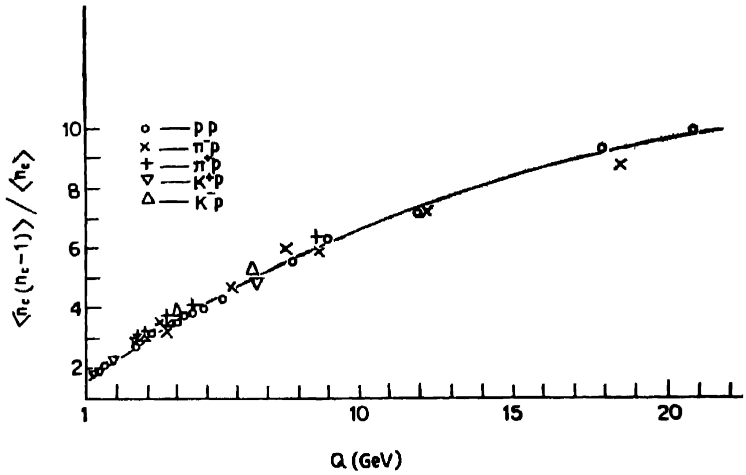

Fig. 1. $< n_c(n_c-1) > / < n_c >$ is plotted as a function of available energy Q. Data: Ammosov *et al.* (1973).

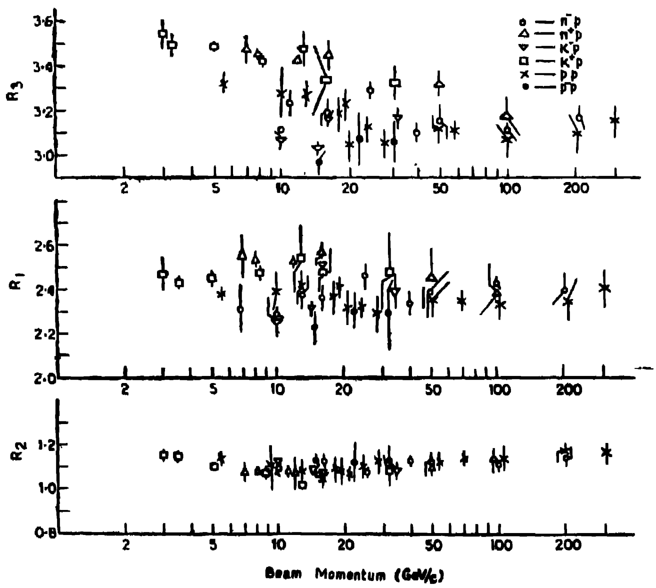

Fig. 2. Plot of R_1, R_2 and R_3 against the beam momentum for pp, $\bar{p}p$, $\pi^{\pm}p$, $K^{\pm}p$ collisions. Data: Ammosov *et al* (1973).

In figure 2, R_1, R_2 and R_3 have been plotted against the beam momenta for the reactions, pp, $\bar{p}p$, $\pi^{\pm}p$ and $K^{\pm}p$. The plot shows clearly that the values of R_1, R_2 and R_3 are almost independent of energy and the type of the reaction. This fact encourages to think that the mechanism responsible for the different features of the multiplicity distribution cannot appreciably differentiate between the six reactions. Since R_1, R_2 and R_3 are independent of energy, they can be used to evaluate the parameters of the multiplicity distributions. For example the gamma distribution proposed by us (Roy *et al* 1974*a*) has a single energy dependent parameter m. The distribution is given by

$$\psi(z) = \frac{m^m}{\Gamma(m)} z^{m-1} e^{-mz}, \qquad \dots \quad (7)$$

where

$$z = n_c/< n_c > \text{ and } \psi(z) = \tfrac{1}{2} < n_c > \sigma_{n_c}/\sum_{n_c} \sigma_{n_c}, \qquad \dots \quad (8)$$

σ_{n_c} being the partial cross section for n_c charged prongs. Assuming R_1 to be energy independent we can write m as

$$m = \frac{1}{a^2}\left\{1 - \frac{a-1}{a(2a-R_1)} \cdot \frac{1}{< n_c >} - \frac{(a-1)(a-R_1+1)}{a(2a-R_1)^3} \cdot \frac{1}{< n_c >^2}\right\}^{-2}, \qquad \dots \quad (9)$$

where $a = \frac{1}{2}\{R_1 - \sqrt{R_1^2-4}\}$.

For pp and π^-p collisions the mean value of R_1 is 2.360, which gives

$$m = 3.262\{1-0.6406/< n_c > -0.3307/< n_c >^2\}^{-2}, \qquad \dots \quad (10)$$

from eq. (7) one obtains

$$D = 0.5536\{< n_c > -0.6406-0.3307/< n_c >\}. \qquad \dots \quad (11)$$

From eq. (10) it can be easily seen that m does not change much when the energy changes from 50 GeV to 1480 GeV in pp collision. So we can replace m by its average value (from 50 GeV/c to 1480 GeV/c) which is 4 and distribution (7) exhibits KNO scaling in pp collision above 50 GeV/c (Roy *et al* 1974*a*, 1974b). Eq. (9) indicates that similar scaling behaviour should be expected in other reactions which is found to be true experimentally. The value of D obtained from eq. (11) gives excellent agreement with the experimental values both in pp and π^-p collisions. It agrees better than the Wroblewski's relation (6). Relation (5) also gives good agreement in pp collision and agrees better than the Wroblewski relation above 19 GeV/c. In π^-p collision it gives much better agreement with the experimental results. It has the additional merit that $< n_c >/D$ tends to 2 at high energies, where as Wroblewski relation gives 1.73 for the limiting value

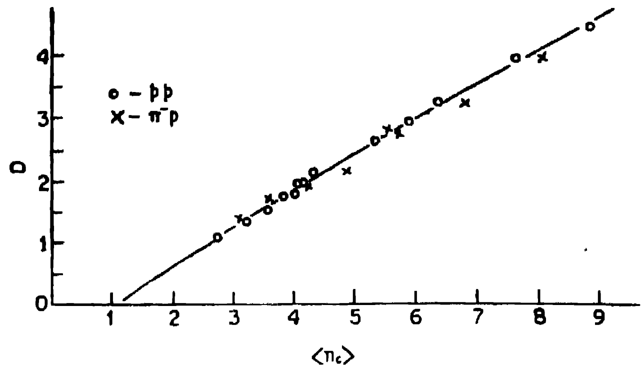

Fig. 3. The dispersion D has been plotted as a function of $< n_c >$. Data : Ammosov *et al* (1973).

at high energies. In figure 3 the dispersion D, as obtained from eqs. (5) and (11), is plotted against the beam momentum. The experimental points for pp and $\pi^- p$ collisions are also shown in the same plot.

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